MICROCOMBUSTORS, MICROREFORMERS, AND METHODS INVOLVING COMBUSTING OR REFORMING LIQUIDS

RELATED APPLICATIONS

This application is a continuation of U.S. patent application Ser. No. 10/434,443, filed May 7, 2003, now U.S. Pat. No. 7,585,472, which was a continuation-in-part of U.S. patent application Ser. No. 10/008,363, filed Nov. 7, 2001, now U.S. Pat. No. 7,077,643.

This invention was made with Government support under DARPA contract #DABT63-99-C-0039. The Government has certain rights in this invention.

FIELD OF THE INVENTION

The invention relates to combustors and steam reformers, and methods involving combusting or steam reforming.

BACKGROUND OF THE INVENTION

The ever-decreasing size of microelectronic devices and the rapid development of microelectromechanical systems (MEMS) have created a great need for high energy density micropower supplies, for example, a power supply for microelectronic devices. Typically, conventional battery technology is used in these applications. However, current battery technology has a very low energy density, on the order of from 0.035 to 0.350 kW_e-hr/kg. An alternative to batteries is to combine a small fuel cell with a micro-hydrocarbon fuel processor. However, thus far, it has not been possible to construct a very small, thermally efficient fuel reformer. An additional problem is that many fuel cells require hydrogen gas having very low levels of carbon monoxide (CO) contamination. Therefore, it is also desirable for a microreformer to produce hydrogen that contains very little CO. Another problem is that instability in microcombustor operation can lead to partial vaporization of the hydrocarbon fuel, if it is liquid, and to less than desired conversion of the hydrocarbons to a hydrogen rich product stream due to the intermittent lack of energy for the endothermic reactions.

Prior attempts to lower CO in a reformate mixture have included: a two stage methanation process conducted at two temperatures over a 2% Rh/alumina catalyst (Van Keulen, U.S. Pat. No. 6,207,307); passage of the reformate through a palladium membrane followed by methanation of residual CO over a catalyst such as Ru, Rh, Pd, Ir, Pt, Ni and Re (Soma et al., U.S. Pat. No. 5,612,012); passage of the reformate through a hydrogen selective membrane followed by methanation of residual CO (Edlund, U.S. Pat. No. 5,861,137); and heating a gas in the presence of a water-gas shift catalyst to reduce the CO content to about 3000 parts per million (ppm), removing water, followed by reaction over Ru or Rh on alumina at below 250 C (Baker et al., U.S. Pat. No. 3,615,164).

Bohm et al. in U.S. Pat. No. 5,904,913 stated that methanol can be reformed at 220 to 280° C. over a Cu/ZnO on alumina catalyst. Bohm et al. reported that they had found that in their apparatus, for a methanol conversion above 98%, with a maximum reaction tube length of 160 cm, a reaction temperature of at least 260° C. should be selected. Lower temperatures would require longer reaction tube lengths. In their apparatus, for a catalyst loading of 1.3 kg, a productivity of 8 Nm^3H_2/h was achieved, which required a minimum temperature of 280° C. for 100% methanol conversion. To lower CO, output from the reforming reaction tubes can be passed to a CO converter to methanate the CO over a titania/alumina/Ru/RuO_x catalyst with a Ru/RuO_x fraction of between 2 to 4% at a maximum temperature of about 200° C.

The prior art processes for reforming hydrocarbons to produce hydrogen suitable for a fuel cell typically require multiple step operations in large and complex apparatus. Thus, there remains a need for microcombustors and fuel reformers which have a very small size, steady performance, and operate at low temperature with low CO output while maintaining high efficiency levels.

SUMMARY OF THE INVENTION

The present invention provides microcombustors and microreformers which can be made with a very small size and which can operate at low temperature. The invention also provides devices utilizing the inventive microcombustors and/or microreformers instead of more conventional devices such as batteries. The invention further provides methods of fuel combustion and steam reforming.

In one aspect of the present invention there is a microcombustor comprising: a first section comprising a combustion fuel channel having an inlet for connecting the microcombustor to a combustion fuel source and an outlet at a top surface of said first section; and a second section disposed next to the first section;

the second section including: a combustion chamber having an inlet in fluid communication with the outlet of the channel of the first section and an outlet capable of evacuating combustion exhaust products; and an exhaust channel having an inlet in fluid communication with the outlet of the combustion chamber and an outlet at a surface of said second section; wherein the combustion fuel channel and the exhaust channel are disposed on a same side with respect to the combustion chamber, so as to form a first heat exchanger.

In a second aspect, the invention provides a microcombustor that includes: a gas inlet connected to a reaction chamber; a liquid feed system connected to the inlet of the reaction chamber; a reaction chamber having an internal volume of 100 mm^3 or less; an outlet connected to the reaction chamber; and a wick, packed tube or capillary tube disposed in at least one of the inlet or the outlet.

In another aspect, the invention provides a steam reformer, comprising a microcombustor as described above; and a third section comprising a reformation channel having an inlet for supplying reformation fuel and an outlet for evacuating reformation products, wherein the exhaust channel and at least a portion of the reformation channel are disposed on a same side with respect to the combustion chamber, so as to form a second heat exchanger.

In another aspect, the invention provides a steam reformer, including: a combustion chamber having an inlet and an outlet, a combustion catalyst being disposed in the combustion chamber; and a reformation chamber having an inlet and an outlet, a reformation catalyst being disposed in the reformation chamber, wherein the combustion catalyst and the reformation catalyst are disposed on opposite faces of a separation plate disposed between the combustion chamber and the reformation chamber.

In a further aspect, the invention provides a steam reformer, that includes: a combustion chamber having an inlet and an outlet, a combustion catalyst being disposed in the combustion chamber; and a reformation chamber having an inlet and an outlet, a reformation catalyst being disposed in the reformation chamber, the combustion chamber and the reformation chamber being disposed around an axis, the inlet and outlet of the combustion chamber being in fluid communication with combustion fuel and combustion exhaust channels,